Mineral Detection of Neutrinos and Dark Matter (MDvDM) 2025

Report of Contributions

https://indico.ijs.si/e/mdvdm

Contribution ID: **2** Type: **not specified**

Atmospheric Neutrino and Dark Matter Detection with Paleo-detectors at the University of Michigan

Wednesday 21 May 2025 10:30 (45 minutes)

The use of ancient minerals as paleo-detectors is an emerging experimental technique capable of transforming the fields of neutrino and dark matter detection. We present the concept of using paleo-detectors to indirectly detect atmospheric neutrinos and dark matter particles (weakly interacting massive particles and beyond) by observing nuclear recoil damage tracks induced by interactions with atomic nuclei. Progress on the use of paleo-detectors for neutrino and dark matter detection at the University of Michigan will be presented. Ongoing research includes target mineral optimization through preliminary imaging, cosmogenic neutron background modeling, and molecular dynamics simulations. Additionally, we anticipate presenting results on irradiation experiments using natural and synthetic paleo-detector minerals to study the formation of damage production in pristine lattices compared to natural lattices.

Do you plan to give the talk in person?

Yes

Primary author: LAVOIE-INGRAM, Emilie (University of Michigan)

Presenter: LAVOIE-INGRAM, Emilie (University of Michigan)

Contribution ID: **3** Type: **not specified**

Experimental Studies Towards Mineral-detectors at KIT

Thursday 22 May 2025 13:30 (45 minutes)

Detection of Dark Matter (DM) is one of the major goals in modern physics. The properties of neutrinos also largely remain a mystery. Mineral-detectors aim to utilize the advent of modern microscopy and computational techniques to read out nm and μm-sized damage features produced by nuclear recoils of DM and neutrinos with nuclei of natural minerals. Karlsruhe Institute of Technology (KIT) is one of the major scientific research institutes in Europe and a unique nexus of expertise and technologies in a wide range of research fields. A new research initiative at the Institute for Astroparticle Physics (IAP) at KIT in cooperation with microscopy experts and geologists aims to conduct experimental studies providing insight into the feasibility of realizing the concept of mineral-detectors. In this talk I will report on the current state of these studies.

Do you plan to give the talk in person?

Yes

Primary author: ELYKOV, Alexey (Karlsruher Institut für Technologie (KIT))

Presenter: ELYKOV, Alexey (Karlsruher Institut für Technologie (KIT))

Contribution ID: **4** Type: **not specified**

Dark matter search using synthetic diamond

Tuesday 20 May 2025 10:30 (45 minutes)

Natural diamond is a type of mineral that forms deep underground in the Earth over several billion years. On the other hand, synthetic diamonds can be manufactured within a few days, with precise control over the amount of impurities. The impurity content in diamond affects its physical properties; for example, it determines its characteristics as a particle detector.
In this talk, I will present the development status of synthetic diamond detectors, primarily motivated by the direct detection of dark matter.

Do you plan to give the talk in person?

Yes

Primary author: UMEMOTO, Atsuhiro (KEK)

Presenter: UMEMOTO, Atsuhiro (KEK)

Contribution ID: **5** Type: **not specified**

Revisiting Q-ball dark matter: closer look at interaction with ordinary matter

Tuesday 20 May 2025 14:15 (45 minutes)

In supersymmetric extensions of the standard model, bosonic partner of quarks (squarks) tend to form an extended objects in the presence of large baryon number, called Q-ball.
Q-balls surviving evaporation and diffusion in the Early Universe contribute to (part of) observed dark matter abundance.
Since Q-ball dark matter has macroscopic mass like gram or heavier (flux limited), it is challenging to search for it in conventional direct detection experiments, though it has a large geometrical cross section like barn or larger.
On the other hand, new opportunity in so-called paleo detector experiments motivates us to examine interaction between Q-ball dark matter and ordinary matter more closely.
There are presumably dominant processes: absorption of nucleon and conversion of nucleon into anti-nucleon.
In this talk, after introducing Q-ball dark matter, we discuss these processes with subtleties.

Do you plan to give the talk in person?

Yes

Primary author: KAMADA, Ayuki (University of Warsaw)

Presenter: KAMADA, Ayuki (University of Warsaw)

Contribution ID: **6** Type: **not specified**

Preliminary ICP-MS analysis of uranium and other trace elements in olivine and muscovite

Wednesday 21 May 2025 14:15 (45 minutes)

Natural minerals have recently gained attention as potential detectors for neutrinos, dark matter, and other unknown particles. However, radioactive elements such as uranium can generate neutrons, alpha recoil, and fission tracks, contributing to background noise. To minimize such interference, minerals with extremely low uranium concentrations are considered ideal candidates. This study aims to evaluate uranium concentrations in olivine and muscovite to assess their suitability for mineral detection of neutrinos, dark matter, and other particles. We analyzed trace elements, including uranium, in hand-picked olivine from harzburgite (Tonga Trench), lherzolite (Mariana Trench), pallasite meteorite, and xenolith in kimberlite (Kimberley, South Africa) and basalt (Damapin, China), as well as muscovite from a pegmatite deposit (Minas Gerais, Brazil). The samples underwent acid digestion, and their trace element compositions were determined using ICP-MS (Agilent 7700x) at Nagoya University. Our results show that uranium concentrations in olivine range from 0.09 to 49.2 ng/g, while muscovite contains 1.8 ng/g. These results indicate that it is essential to account for potential background signals arising from uranium concentrations on the order of 10 ng/g in mineral detection. Therefore, precise quantification of uranium is essential when selecting minerals for particle detection.

Do you plan to give the talk in person?

Yes

Primary authors: Dr KOZAKA, Yukiko (Kanazawa University); KATO, Takenori (Nagoya University)

Co-authors: Dr ASAHARA, Yoshihiro (Nagoya University); Dr KOUKETSU, Yui (Nagoya University); Prof. MICHIBAYASHI, Katsuyoshi (Nagoya University)

Presenter: KATO, Takenori (Nagoya University)

Contribution ID: **7** Type: **not specified**

Imaging of color center tracks in lithium fluoride at UZH

Thursday 22 May 2025 15:30 (45 minutes)

Lithium fluoride (LiF) is a promising candidate for low-energy nuclear recoil detection with color centers. It exhibits relatively low sensitivity to ionizing radiation and the light lithium and fluorine nuclei enhance the sensitivity for spin-dependent low-mass dark matter and neutrino detection. Particle-induced color center tracks can be read out by selective plane illumination microscopy (SPIM) with well-separated excitation and emission wavelenghts in the visible spectrum.
At the University of Zurich, the open-source light-sheet fluorescence microscope mesoSPIM allows for the readout of samples with volumes of tens of cubic centimeters. Recently, fast-neutron tracks, fission tracks from thermal neutron capture on ^{6}Li, and track candidates from cosmic rays could by identified within cm^3-size samples and were analyzed quantitatively. This marks an important stepping stone towards larger practical detectors for dark matter searches, neutrino detection at nuclear reactors or sensitive neutron detection. The contribution will present recents results, show the imaging process and lay out the analysis techniques for three-dimensional tracks.

Do you plan to give the talk in person?

No

Primary author: WITTWEG, Christian (University of Zurich)

Presenter: WITTWEG, Christian (University of Zurich)

Contribution ID: **8** Type: **not specified**

Probing Ancient Cosmic Ray Flux with Paleo-Detectors and the Launch of the PRIμS Project.

Wednesday 21 May 2025 11:15 (45 minutes)

Paleo-detectors offer a unique opportunity to probe the long-term history of cosmic ray flux, potentially revealing evidence of historical nearby high-energy astrophysical events. In this contribution, we present our recently published work demonstrating that evaporites formed during the Messinian Salinity Crisis (~6 Myr ago) could provide an ideal natural target to study secondary cosmic ray interactions. By modeling the density of nuclear recoil tracks preserved in these minerals and taking into account the deposition and shielding rate in the geological event, we show that percent-level variations in the primary cosmic ray flux could be detected, extending the reach of paleodetectors beyond dark matter and neutrino searches to cosmic ray paleo-astrophysics. We also introduce PRIμS, an INFN-funded experimental effort that is the natural extension of our phenomenological work. Using high-throughput optical microscopy and plasma etching techniques, PRIμS aims to analyze a variety of samples, with a focus on halite and other evaporites, with the goal of validating theoretical models and refining background estimates for future paleo-detector applications.

Do you plan to give the talk in person?

Yes

Primary author: GALELLI, Claudio (INFN Milano)

Co-authors: APOLLONIO, Lorenzo (INFN Milano); Dr CACCIANIGA, Lorenzo (INFN Milano)

Presenter: GALELLI, Claudio (INFN Milano)

Contribution ID: **9** Type: **not specified**

Search for Long-Lived Particles in Macroscopic Matter

Tuesday 20 May 2025 15:30 (45 minutes)

We introduce a novel experimental method that enables sensitivity to a single anomalously heavy particle within a large volume of macroscopic matter. We propose to apply this method to colliders, ancient rocks, and other materials to search for heavy, long-lived BSM particles such as gluinos, charged dark matter, and magnetic monopoles.

Do you plan to give the talk in person?

Yes

Primary authors: Mr EBADI, Reza (University of Maryland); Prof. GONSKI, Julia (SLAC); Prof. GRAHAM, Peter W. (Stanford University); Prof. RAJENDRAN, Surjeet (Johns Hopkins University); Prof. RAMANI, Harikrishnan (University of Delaware); Dr TANIN, Erwin (Stanford University); WONG, Samuel (Stanford University)

Presenter: WONG, Samuel (Stanford University)

Contribution ID: **10** Type: **not specified**

Current status of DMICA: exploring Dark Matter in natural muscovite MICA

Thursday 22 May 2025 11:15 (45 minutes)

In 1995, Snowden-Ifft and colleagues used 500-million-year-old muscovite mica to establish one of the most stringent dark matter cross-section limits, achieving an exposure of 0.08 square millimeters. They etched cleaved mica surfaces to read out nuclear recoil tracks, visible as pits, with atomic force microscopy (AFM), then estimated the recoil energies from pit depths. We are now planning the DMICA experiment to build on this work, covering 800 square centimeters —equivalent to a one-ton-year exposure. This dramatic increase becomes feasible by employing white light interferometry (WLI) instead of AFM to scan the etched mica surfaces. Although WLI offers rapid scanning, it also presents challenges, such as pit depth (and thus recoil energy) underestimation caused by the instrumental transfer function. This presentation will discuss the current status of DMICA, focusing on our deconvolution technique to restore pit depths and on measurements of the mica's vertical etch rate, which is critical for assessing the etched volume and thus the exposure of the experiment.

Do you plan to give the talk in person?

Yes

Primary author: HIROSE, Shigenobu (JAMSTEC)

Presenter: HIROSE, Shigenobu (JAMSTEC)

Contribution ID: **11** Type: **not specified**

Towards Quantum Sensing for Directional Dark Matter Detection Using Nitrogen Vacancy Centers in Diamond

Tuesday 20 May 2025 09:15 (45 minutes)

WIMP dark matter detection is increasingly constrained by the "neutrino fog," where solar neutrino backgrounds mask potential signals. To address this challenge, we are developing a diamond-based detector that leverages nitrogen-vacancy (NV) centers for directional event discrimination. WIMP or solar neutrino interactions induce nuclear recoils that create permanent 10–100 nm damage tracks in diamond, which can be imaged using quantum sensing techniques. Since our last report at MDvDM, we have (1) detected artificial damage tracks from ~1 MeV single-ion impacts, (2) developed a light-sheet quantum diamond microscope for high-precision, high-volume strain and fluorescence imaging, and (3) conducted molecular dynamics simulations of damage track formation. Lastly, we will also present ongoing work towards three-dimensional super-resolution imaging of these tracks using NV-based quantum sensing.

Do you plan to give the talk in person?

No

Primary author: ANG, Daniel (University of Maryland)

Co-authors: GILPIN, Andrew (University of Maryland); TANG, Jiashen (University of Maryland); CAMP, Mason (University of Maryland); SHEN, Maximilian (University of Maryland); Prof. WALSWORTH, Ronald (University of Maryland)

Presenter: ANG, Daniel (University of Maryland)

Contribution ID: **12** Type: **not specified**

Surrogate sample preparation with neutron irradiation

Wednesday 21 May 2025 13:30 (45 minutes)

Well-characterized neutron irradiation is an indispensable tool in the quest to understand characteristic defects produced in minerals by coherent elastic neutrino-nucleus scattering and hypothetical dark matter particles. This talk will introduce and discuss opportunities for high-fidelity, quantifiable, and repeatable neutron irradiations at a wide range of energy scales. Practical sources accessible to this research program will be discussed, along with supporting simulations and protocols for their use.

Do you plan to give the talk in person?

Yes

Primary author: JOVANOVIC, Igor (University of Michigan)

Presenter: JOVANOVIC, Igor (University of Michigan)

Contribution ID: **13** Type: **not specified**

Artificial formation of alpha recoil tracks using an americium source

Wednesday 21 May 2025 15:30 (45 minutes)

Alpha recoil track (ART) is a lattice defect formed by the alpha decay of heavy nuclides. It is necessary to investigate appropriate etching conditions, surface properties of a mineral, and the ART annealing characteristics upon heating to apply ART observation to the dating and thermal history study of various minerals. This study aims to develop a method for artificially forming ART so that the shape and properties of etched ART in various minerals can be studied in the future.
A 300 Bq americium source was used to irradiate muscovite, in which the ARTs were well observed in previous studies, for various time intervals after annealing treatment to erase all naturally occurring ARTs, and the samples were observed using phase contrast microscopy after chemical etching. The ART areal density formed on the sample surface showed a linear relationship against irradiation time, indicating the feasibility of using Am source to artificially form ARTs on a mineral surface. However, the size distribution of the artificial ARTs were larger than that the naturally observed ARTs.
The annealing experiment on the artificially formed ARTs showed that the size distribution of natural ARTs could be indicative of annealing at ambient temperature over a geologically long period time, or ARTs could have been annealed in the recent past at a slightly higher temperature (150 – 200℃) given their uniform size distribution. We cannot rule out the possibility that the observed natural ART-like tracks were formed by the movement of smaller nuclei (e.g., movement of major mineral-forming-atoms by cosmic ray irradiation),assuming that the track size reflects the energy and mass of moved nuclei. Further detailed studies of annealing behavior and track formation processes by the movement of various atoms are required to reach a definitive understanding.

Do you plan to give the talk in person?

Yes

Primary author: Mr NAKASHIMA, Taiki (Kanazawa University)

Co-authors: HASEBE, Noriko (Institute of Nature and Environmental Technology, Kanazawa University); Prof. YOKOYAMA, Akihiko (Kanazawa University); Dr YAMADA, Norihiro (Kanazawa University); Dr TAKAMIYA, Koichi (Kyoto University); Mr IINUMA, Yuto (Kyoto Unniversity)

Presenter: HASEBE, Noriko (Institute of Nature and Environmental Technology, Kanazawa University)

Contribution ID: **14** Type: **not specified**

Reflection on High Mass Dark Matter and Searches in Minerals

Friday 23 May 2025 09:15 (45 minutes)

In this talk I will review high mass dark matter models that motivate searches for dark matter in minerals. After detailing modern developments in high mass dark matter searches, I will review past searches in mic, and make some comments on technical challenges and opportunities moving forward.

Do you plan to give the talk in person?

No

Primary author: BRAMANTE, Joseph (Queen's University)

Presenter: BRAMANTE, Joseph (Queen's University)

Contribution ID: **15** Type: **not specified**

First-principles screening of mineral candidates for dark matter detection with the PALEOCCENE technique

Tuesday 20 May 2025 13:30 (45 minutes)

At the lowest threshold for particle detection using the PALEOCCENE technique, nuclear recoils may result in only small numbers of single vacancy or interstitial defects. When such defects are optically active color centers, they can be used to image damage tracks down to atomic-scale resolution. First principles calculations are an effective approach for screening large numbers of minerals based on their propensity to form color centers from nuclear recoils. We begin by describing the methodology for calculating the electronic and optical properties of color centers, showing how careful tuning of the hybrid functional to simultaneously satisfy the generalized Koopman's theorem and reproduce the experimental band gap, enables precise prediction of emission wavelengths and formation energies. We demonstrate the accuracy of this method by comparing with experimental results in lithium fluoride. Finally, we conclude by showing how this method can be used to screen candidate materials for mineral detection of dark matter, and identify systems where single vacancy and interstitial defects are stable, optically bright color centers.

Do you plan to give the talk in person?

Yes

Primary author: IVANOV, Vsevolod (Virginia Tech)

Presenter: IVANOV, Vsevolod (Virginia Tech)

Contribution ID: **16** Type: **not specified**

Mineral detectors on the moon

Friday 23 May 2025 13:30 (45 minutes)

Terrestrial mineral detector searches for signatures of new physics can be challenging due to the large backgrounds oringiating from cosmic ray interactions with the Earth's atmosphere. However, the Moon offers a reprieve from these backgrounds, since the conventional components of the cosmic-ray-induced fluxes of muons and neutrinos are significantly suppressed due to the Moon's lack of atmosphere. We discuss the physics potential of a futuristic mineral detector experiment on the Moon, particularly in the context of a search for proton decay signatures, given proton lifetimes which would not be possible to detect with a terrestrial mineral detector experiment and could possibly exceed the sensitivity of DUNE and Hyper-Kamiokande.

Do you plan to give the talk in person?

Yes

Primary author: STENGEL, Patrick (Jožef Stefan Institute)

Presenter: STENGEL, Patrick (Jožef Stefan Institute)

Contribution ID: **17** Type: **not specified**

Nuclear recoil detection with color centers in bulk lithium fluoride

Tuesday 20 May 2025 11:15 (45 minutes)

We present results on nuclear recoil detection based on the fluorescence of color centers which are created by recoil cascades in lithium fluoride. We use gamma rays, fast and thermal neutrons, and show that this type of detector is rather insensitive to gamma rays. Furthermore, we establish that the shape of the fluorescent spectrum is different for neutron and gamma irradiation, respectively. We use light-sheet fluorescence microscopy to image nuclear recoil tracks from fast and thermal neutron interactions deep inside a cubic-centimeter sized crystal and demonstrate automated feature extraction using machine learning tools. The number, size, and topology of events agree with expectations. In summary, these results constitute the first step towards 10-1000g scale detectors with single event sensitivity for application to the detection of dark matter particles, reactor neutrinos, and neutrons.

Do you plan to give the talk in person?

Yes

Primary author: HUBER, Patrick (Virginia Tech)

Presenter: HUBER, Patrick (Virginia Tech)

Contribution ID: **18** Type: **not specified**

Ultra-heavy Dark Matter Detection with the Paleo Detector

Friday 23 May 2025 11:15 (45 minutes)

Currently, various dark matter searches are being conducted worldwide, yet its properties remain unknown, and a vast parameter space is still unexplored. Ultra-heavy dark matter with a mass of 10^10 GeV/ or more is expected to exist, potentially as composite dark matter. Several theoretical candidates have been proposed in particle physics, some of which offer intriguing solutions to fundamental problems in the field. Due to its extremely low flux, detecting such ultra-heavy dark matter requires innovative approaches. Paleo-detectors with timescales of approximately 100 million years have significant potential for capturing exotic particle signatures. Additionally, meteorites containing olivine are promising targets for rare event searches, including the detection of ultra-heavy elements.Our current research focuses on evaluating track formation capabilities in muscovite mica and olivine. In parallel, we are developing an optical microscope scanning system based on nuclear emulsion scanning technology. In this talk, we will present the current status of our study and the insights gained so far.

Do you plan to give the talk in person?

Yes

Primary author: NAKA, Tatsuhiro (Toho University)

Presenter: NAKA, Tatsuhiro (Toho University)

Contribution ID: **19** Type: **not specified**

Welcome

Tuesday 20 May 2025 09:00 (15 minutes)

Do you plan to give the talk in person?

Presenters: HIROSE, Shigenobu (JAMSTEC); STENGEL, Patrick (Jožef Stefan Institute)

Contribution ID: **20** Type: **not specified**

Discussion

Tuesday 20 May 2025 16:15 (45 minutes)

Do you plan to give the talk in person?

Contribution ID: **21** Type: **not specified**

Astrophysical Neutrino Overview

Wednesday 21 May 2025 09:15 (45 minutes)

Do you plan to give the talk in person?

Presenter: HORIUCHI, Shunsaku (Science Tokyo)

Contribution ID: **22** Type: **not specified**

Olivines from Archean komatiites

Do you plan to give the talk in person?

Presenter: MCDONOUGH, William F. (AIMEC, Tohuku University)

Contribution ID: **23** Type: **not specified**

Discussion

Wednesday 21 May 2025 16:15 (45 minutes)

Do you plan to give the talk in person?

Contribution ID: **24** Type: **not specified**

Dark Matter Overview

Thursday 22 May 2025 10:30 (45 minutes)

Do you plan to give the talk in person?

Presenter: YIN, Wen (Tokyo Metropolitan University)

Contribution ID: **25** Type: **not specified**

TBA

Thursday 22 May 2025 09:15 (45 minutes)

Do you plan to give the talk in person?

Presenter: KELSO, Chris (University of North Florida)

Contribution ID: **26** Type: **not specified**

Advanced Microscopy in the Study of Tracks in Natural and Synthesized Quartz

Thursday 22 May 2025 14:15 (45 minutes)

This research focuses on the study of tracks in quartz, an abundant mineral in the earth. Both synthesized single crystal quartz and natural quartz samples from deep underground have been studied. We introduced heavy gold ions into the synthesized quartz samples at different irradiation fluences. The samples were then studied using advanced transmission electron microscopy. We have found isolated tracks that have been generated in the surface regions down to several micrometers. For natural quartz samples, we plan to study the microstructure/microchemistry of the crude samples and then image pre-existing tracks and other defects. Further treatments may be performed, such as annealing and ion irradiation, to study the variation in track formation in natural versus synthetic quartz. Other techniques like high- resolution X-ray imaging and atomic force microscopy will also be used for characterizing samples at relatively large volume. Additionally, atomic force microscopy will be used for topological measurements of the tracks. Experimental data will be compared to theoretical models.

Do you plan to give the talk in person?

Co-authors: SUN, Kai (University of Michigan); LAVOIE-INGRAM, Emilie (University of Michigan); SPITZ, Joshua (University of Michigan)

Presenter: SUN, Kai (University of Michigan)

Contribution ID: **27** Type: **not specified**

Discussion

Thursday 22 May 2025 16:15 (45 minutes)

Do you plan to give the talk in person?

Contribution ID: **29** Type: **not specified**

Exploring Very Heavy Dark Matter

Friday 23 May 2025 10:30 (45 minutes)

We review current constraints on very heavy dark matter. While most of the constraints on heavy dark matter rely on indirect searches with neutrinos, gamma rays and cosmic rays, direct searches enable us to probe certain parameter space that has not been explored. Some science cases of DMica will be discussed.

Do you plan to give the talk in person?

Yes

Primary author: MURASE, Kohta (Penn State University)

Presenter: MURASE, Kohta (Penn State University)

Contribution ID: **30** Type: **not specified**

Closing

Presenters: HIROSE, Shigenobu (JAMSTEC); STENGEL, Patrick (Jožef Stefan Institute)

Contribution ID: **31** Type: **not specified**

Rock samples from ocean drilling

Friday 23 May 2025 14:15 (45 minutes)

- "Chikyu"was the one of the leading scientific drilling vessels in International Ocean Discovery Program (IODP), and continues to be the same in the next International Ocean Drilling Programme3 (IODP3 = IODP-cubed). This presentation introduces Chikyu's specifications, capabilities, wireline coring techniques, Small-Diameter Rotary Core Barrel (SD-RCB) system which was developed by JAMSTEC especially, and Chikyu's past coring operation. (Yokoyama & Sakurai)
- This presentation will introduce where and how to sample natural minerals that should work well as paleo-detectors. In particular, we will focus on olivine, which is often found in rocks that contain less radioactive elements, and how to sample it. Where on earth have they been found? What geological age are they from? How deep are they from? Since scientific drilling is a powerful method to take deep rock samples, I will show how to access these samples. (Abe)

Do you plan to give the talk in person?

Yes

Primary authors: ABE, Natsue (JAMSTEC); SAKURAI, Noriaki (JAMSTEC); YOKOYAMA, Takahiro (JAMSTEC)

Presenters: ABE, Natsue (JAMSTEC); SAKURAI, Noriaki (JAMSTEC); YOKOYAMA, Takahiro (JAMSTEC)

Contribution ID: **32** Type: **not specified**

Disucssion

Friday 23 May 2025 16:15 (45 minutes)

Contribution ID: **33** Type: **not specified**

Olivines from Archean Komatiites

Friday 23 May 2025 15:30 (45 minutes)

Olivines from komatiites represent some of the best available mineral detectors for neutrino and dark matter searches. Komatiites are Mg-rich lavas that are almost exclusive to the Archean (>2.5 billion years old) time period of Earth's history. The high MgO contents of these lavas (typically 25 wt% MgO (Arndt, 2023), cf., 10 wt% MgO for modern basalts) reveal that their eruption temperatures were much higher than what is observed today for basalts erupted at mid-ocean ridges and places like Hawaii.

Nisbet et al. (1987) was the first paper to report melt inclusions (10-50 micron diameter) in fresh olivines from 2.7 billion-year-old Belingwe komatiites in Zimbabwe. This amazing discovery revealed that these lavas are incredibly well preserved. Following this discovery, McDonough and Ireland (1993) reported ionprobe trace element data for these melt inclusions documenting that fluid mobile elements (e.g., K, Sr, and Ba) were still present in their original relative abundances. These data also provided the opportunity to constrain the tectonic environment for komatiite genesis. Since then, other locations of unaltered komatiites hosting olivine-bearing melt inclusions have been identified (Sobolev et al., 2016; Asafov et al., 2018), including locations that are up to 3.3 billion years old (Sobolev et al., 2019).

An unknown in the history of these komatiites is the depth for which they have remained during their multibillion-year residence in the continental crust. We have quantitative constraints (± ~1% uncertainties from radiometric ages) on the eruption and emplacement ages of these lavas. Currently, we do not have quantitative constraints on the depth of burial versus time. Their freshness tells us that these lavas were not at the surface where there is abundant water, which drives almost all alteration processes. That these rocks are >2.5 billion years old and still fresh means that they have been held in some "special place"for a long time to preserve them. A standard crustal geotherm is typically between 10°C and 20°C/km. Therefore, the maximum temperature should only be about 100°C at 5 km depth. This condition is usually not enough to anneal tracks, but might alter these minerals. However, their preservation tells us that the system has been relatively dry over their history and does not have active alteration processes.

There is no quantitative constraint on the history of crustal depth of these lavas; however, reconstruction of the average depth of burial may be possible with strict constraints on their age, location, and U-Th concentrations. The muon flux and, correspondingly, the differential cosmogenic neutron flux, vary as a function of depth and composition of the rock overburden (Fedynitch et al., 2022; Woodley et al., 2024; Marino et al., 2007; Mei and Hime, 2005). The relative shape of the induced recoil spectrum is expected to remain constant with depth, varying only in amplitude. This spectrum can be fitted - and thus the average depth or cosmogenic signal 'reconstructed'- with experimental data and simulation. When using these ancient minerals to detect atmospheric neutrinos, the sensitivity of the required paleo-detector is much less influenced by depth. Tracks induced by nuclear recoils from atmospheric neutrinos can be up to a millimeter in length, exceeding track lengths caused by cosmogenic neutrons. Komatiitic olivines from ages ancient to recent (3300 to 90 million years ago) provide the best possible exposure and purity for atmospheric neutrino detection, allowing us to map changes in the cosmic ray rate throughout Earth's history.

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Woodley, W., Fedynitch, A., Piro, M.C., 2024. Cosmic ray muons in laboratories deep underground. Phys. Rev. D 110, 063006. URL: https://link.aps.org/doi/10.1103/PhysRevD.110.063006, doi:10.1103/PhysRevD.110.063006.

Do you plan to give the talk in person?

Yes

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